

Acela Track Spiral Geometry Degradation Rates Based on 5 Years of Data - updated

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ABSTRACT

Amtrak has undertaken two tests of improved spiral geometry developed by the author. The first test was quite successful. The second test was less successful because of a problem in tamper operation that is unrelated to spiral geometry but was valuable because it brought that problem to light.

The work reported here is based on about 5.5 years worth of geometric information for the tracks traversed by the Acela trains that Amtrak has been gathering on a semi-monthly basis for a number of years. It focuses on change with time of RMS values of line and surface roughness in and close to spiral transition curves.

The work was undertaken with two goals. One goal was to determine whether or not costs incurred by Amtrak to maintain track geometry would be reduced if Amtrak adopted improved spiral geometry more generally. The answer to this question is shown to be no. The other goal was to see the results of the two tests of improved spiral geometry in a broader context and to better understand the difficulty in the second test. The cause of that difficulty is explained and is interesting.

Independent of the foregoing matters, the study can assist in general understanding of geometric behavior over time of ballasted track as maintained by Amtrak.

1. MOTIVATION

The author has been interested for a number of years in the geometry of railroad track transition curves most of which are spirals. In previous papers he and co-authors have described near optimal principles for design of transition curves, means for applying the near optimal spiral geometry to new track and to existing ballasted track, examples of how vehicle dynamic responses to near optimal spirals are improved compared to responses of the same vehicles to traditional “linear” spirals, and results of the first of two tests of improved spiral geometry by Amtrak.

While simulations using NUCARS, VAMPIRE, and Gensys have shown that improved spiral geometry brings benefits and while the Amtrak tests have shown positive results, the passenger and freight rail industries have gotten along with traditional transition curves for a very long time and have not yet judged it prudent to undertake the engineering efforts that would be needed for a switch to improved spiral geometry. In the USA the appeal of improved spiral geometry is diminished because most American track embodies irregularity that causes more vehicle motion fluctuation than that due to the dynamic defects of traditional spiral geometry. That is, the benefit of improved spiral geometry would be obscured by the “noise”.

Another perspective on spiral geometry can be developed by asking whether it could be expected to reduce track maintenance costs. One can develop that sort of perspective by comparing rates of track irregularity increase for improved spirals with corresponding rates for traditional spirals. Such a comparison can be developed using the track geometry recordings that Amtrak has been making about twice a month for a number of years on its main line tracks between Washington, DC and Boston, MA. The geometry recording is done using either of two specially equipped coaches one of which, car 10003, gets inserted in Acela train consists that are typically run from Washington to Boston on one day and run

back to Washington the following day. Measured values are recorded once per foot as determined from an angular encoder on one of the wheel sets.

2. EXAMINATION OF THE DATA

Software developed by the present author for dealing with the geometry car data includes facilities for visualizing the data. It lets the user select up to ten measuring runs from among those available and display the trace for a given quantity from each run in a way that allows easy visual comparison. Traces sometimes show that geometry was altered between successive measuring runs by track work. In a majority of cases the data look reasonable. However, traces occasionally show signal anomalies, and some of the available geometry run recordings were not included in this study for that reason.

Figure 1 provides a sample view of some gage data with one anomaly, namely a brief dropout of the gage signal for the run labeled 307044. It also shows that ties or rail fasteners were altered in the neighborhood of 2400 feet between run 307023 and run 307044.

Put fig 1 here

3. PROCESSING OF GEOMETRY CAR DATA.

The geometry car data used in this study all come from runs of geometry car 10003 between January 2004 and July 2009. There are two gaps in the sequence of run dates. One lasted about 4 months during the summer of 2005 when Acela train operation was suspended due to a brake gear problem. The other was during the last 2 months of 2008 when the geometry car was undergoing maintenance. This study looks at sections of track that were traversed in the same direction by a majority of geometry car train runs. The distance covered by each run is divided into sections with a new section starting each time the train with the measuring car crosses a line boundary or changes track. The lines on the Northeast Corridor are labeled Philadelphia (AP), New Jersey (AN), New York West (AZ), New York East (AT), Hellgate (AG), Metro North (MN), and Boston (AB). The “covered sections” that were selected and the number of runs for each one are shown in Table 1.

Line	Track	Run direction (+1 means from NYC, -1 means to NYC)	Start mile	End mile	Number of runs covering only the section	Number of runs covering at least the section	Number of runs covering at least the section times number of miles in section
AB	1	-1	222	75	1	40	5880
AB	2	1	75	224	3	54	8046
AG	1	-1	16	7	9	48	432
AG	2	1	6	17	51	51	561
AN	2	-1	20	9	28	58	638
AN	2	-1	82	25	3	54	3078
AN	3	1	9	20	38	52	572
AN	3	1	25	85	38	47	2820
AP	2	-1	24	3	38	62	1302
AP	2	-1	96	30	23	60	3960
AP	2	-1	127	114	26	59	767
AP	3	1	3	59	46	54	3024
AP	3	1	74	133	6	47	2773

TABLE 1: 13 Sections Of Track Covered By Numerous Geometry Car Measuring Runs And Used As Basis For Study.

For each of the covered sections shown in Table 1 each run that contributes to the coverage has the location of each milepost and the number of feet in each mile adjusted based on comparison of curvature and gage fluctuation patterns among runs covering the section so that given intervals of the adjusted data for different runs describe the same interval of physical track. Similar but more comprehensive longitudinal alignment of the Amtrak geometry car data has been done for a number of years by Rome Navigation as described in reference (2).

4. FOCUS ON TRACK ROUGHNESS IN SPIRALS.

Spirals abutting tangent track were identified within the listed sections based on the measured curvature. The number of spirals identified is 1054. The measures of geometric quality used here are the three track roughness RMS values listed in Table 2. The RMS values are based on measurements in inches. For each spiral these measures were applied to the spiral itself plus 200 feet of tangent or curved track adjacent to the spiral at each end.

Degree of freedom	Description of measure:
Horizontal alignment	RMS value of left alignment based on 31 foot chord (The channel data have the mean offset due to horizontal curvature subtracted out.)
Surface (i.e., vertical profile)	RMS value of mean of left and right profile based on 31 foot chord (The channel data have the mean offset due to vertical curvature subtracted out.)
Cross level	RMS value of cross level "fluctuation" where "fluctuation" at a point is defined as the mean of crosslevel values between 1 and 15 feet away in each direction minus the mean of crosslevel values from 16 to 30 feet away in each direction.

TABLE 2: Measures Used To Represent Roughness Of Track Geometry.

5. PLOTS OF TRACK ROUGHNESS VERSUS TIME

Table 3 below lists 19 spiral roughness behaviors and features found in the study. Eight of the behaviors are illustrated in figures 2 through 9, which show geometric quality versus time for representative

spirals. (The article length limit precludes illustrating all of the features.) In Table 3 stability refers to the rate of change of a roughness RMS value with time, and a value that is stable can be undesirably high.

Line Sta-bility	Surface Sta-bility	Feature of interest ≤ High if slope < 5e-6, ≤ Decent if slope < 3e-5, ≤ Fair if slope < 2e-4	Figure showing example	Approx. # spirals of type in mile range of track of line:	
				75->224 track 2 line AB	25->85 track 3 line AN
High	High		2	45	14
High	Decent	This is the most common type.	3	131	31
Decent	High			2	0
Decent	Decent		4	15	7
High	Fair	Requires regular maintenance.	5	24	6
Fair	High	ditto		1	0
Decent	Fair	ditto		22	4
Fair	Fair	ditto		7	1
High	Poor	Requires frequent maintenance.	6	0	1
Decent	Poor	ditto		0	2
Fair	Poor	ditto		1	1
		Spirals exhibiting seasonal breathing.	7	11	2
		Spirals on which tamping causes roughness to oscillate.	8	3	4
		Spirals whose early roughness has been reduced.	9	4	7
		Spirals in which line degrades faster than surface; infrequent.		3	1
		Spirals in which the line roughness decreases spontaneously due possibly to rails spending most of the time in tension.		27	11
		Spirals that appear hard to measure; their line roughness RMS values jump around and include high spikes and/or dropouts.		13	2
		Spirals on which a tamping or something else caused stability of the line or surface to change.		9	2
		Spirals on which a tamping caused roughness to increase. (May relate to roughness oscillation.)		5	5

TABLE 3: Counts Of Geometric Stability Patterns And Of Additional Features For Subject Spirals On Two Track Intervals. (Classification Values Refer To Slope Labels Of Trend Lines In Figures.)

Trend line end points in the following figures were selected based on perceived indications of maintenance or change in behavior and without independent knowledge of track maintenance histories.

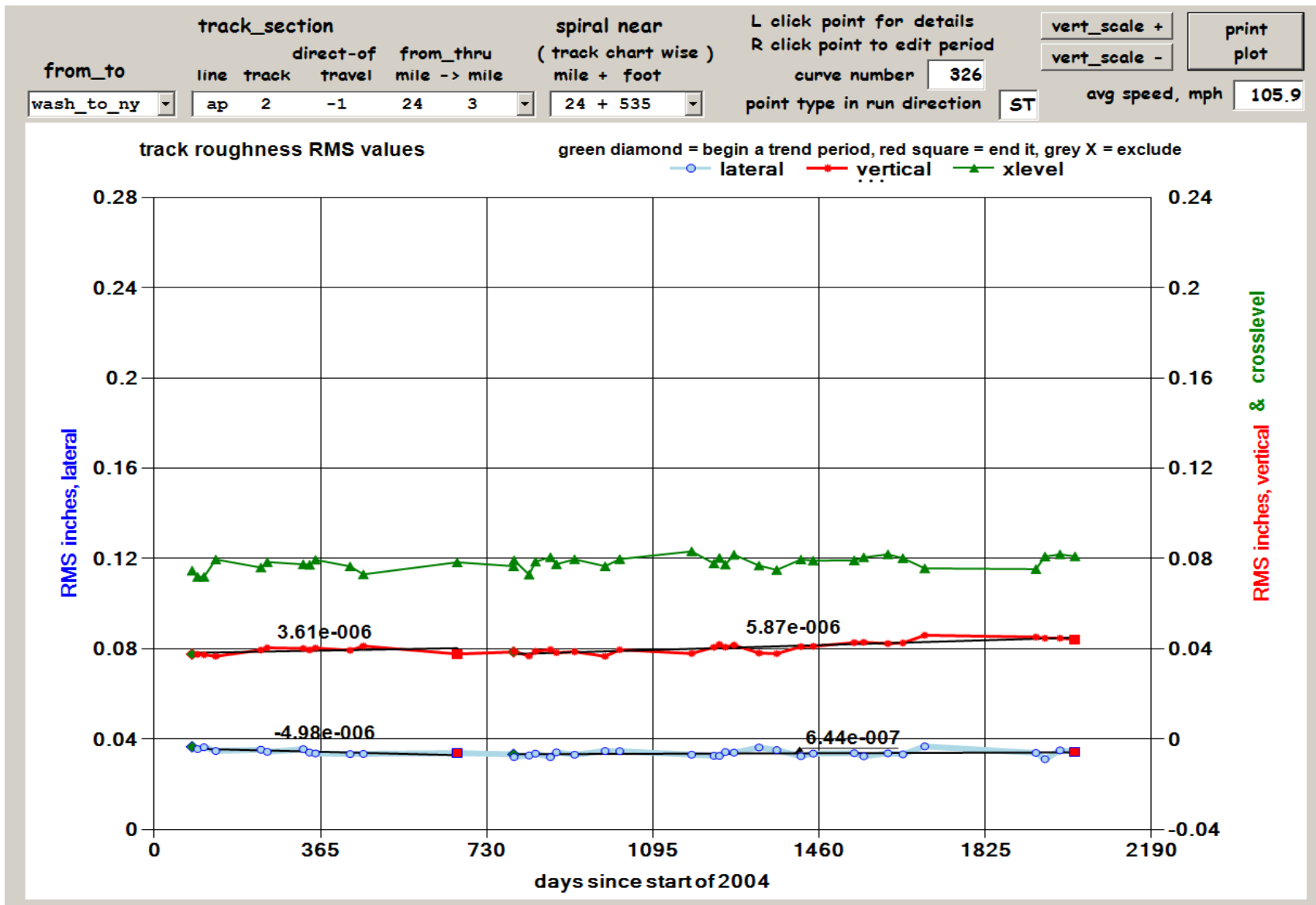


FIGURE 2: Spiral in which line and surface are both stable. Numbers above trend lines show rate of change of RMS value per day. Trend lines are created pursuant to user selection of the end points. Curve Point Type Shown Is Based on Direction of Travel. Foot Value Is Approximate.

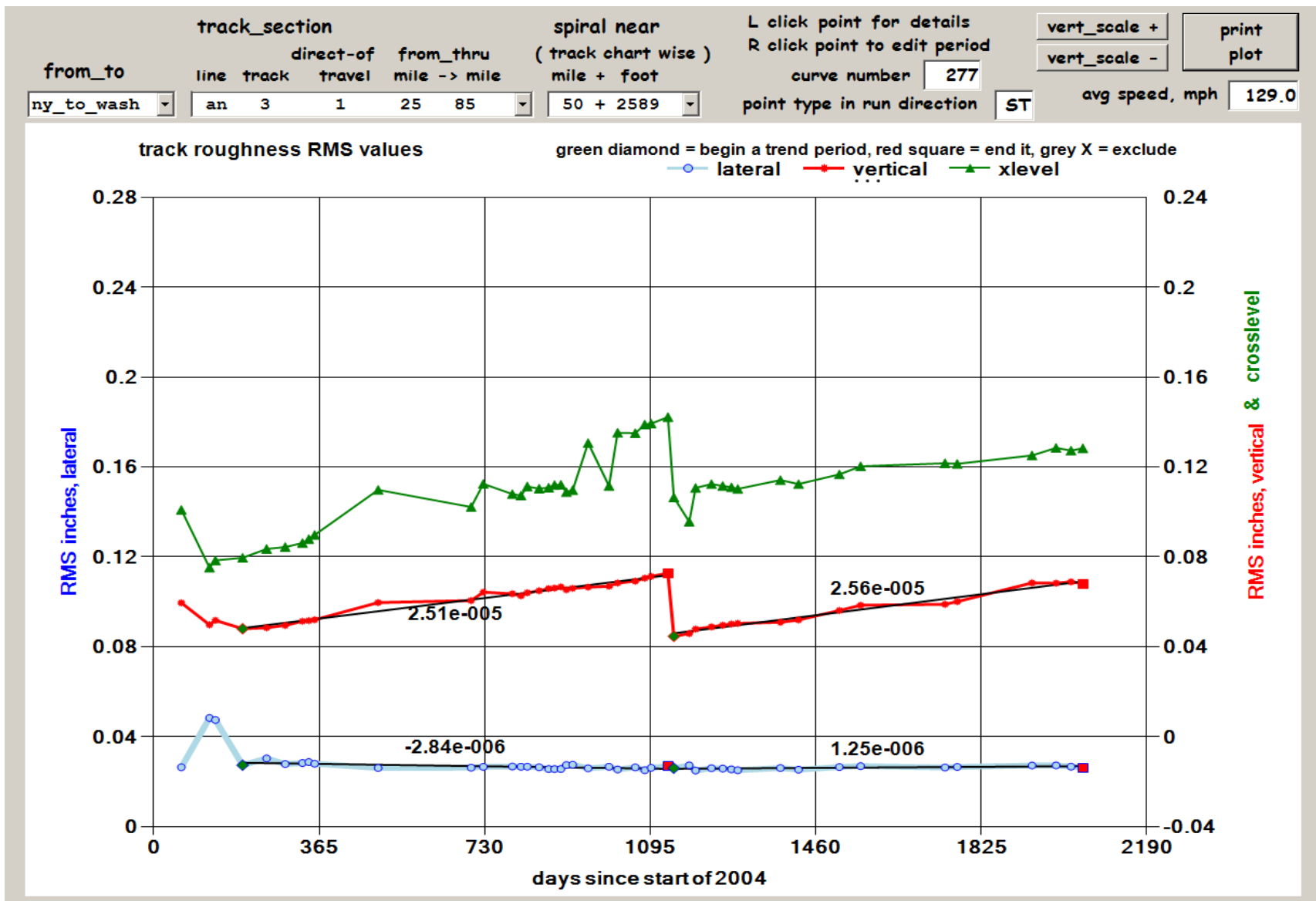


FIGURE 3: Spiral with stable line and with surface degrading at a moderate rate. The surface trace shows tamping early in 2007. Spontaneous improvement of line before 2007 followed by normal slow degradation of line thereafter is a common feature.

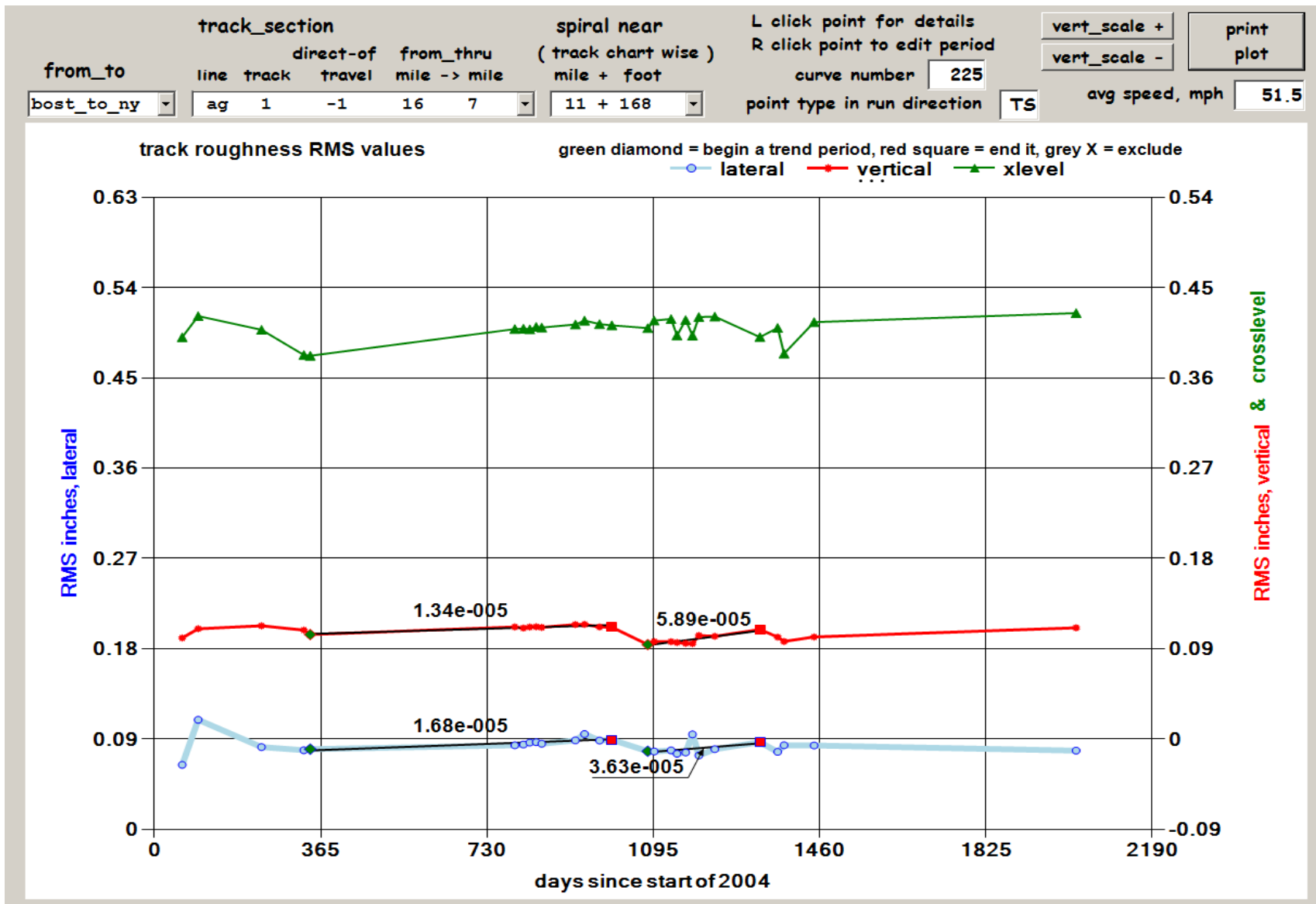


FIGURE 4: Spiral in which line and surface both degrade at moderate rates. The rate of increase of RMS value is almost always greater for surface than for line. The vertical scale is contracted compared to neighboring figures.

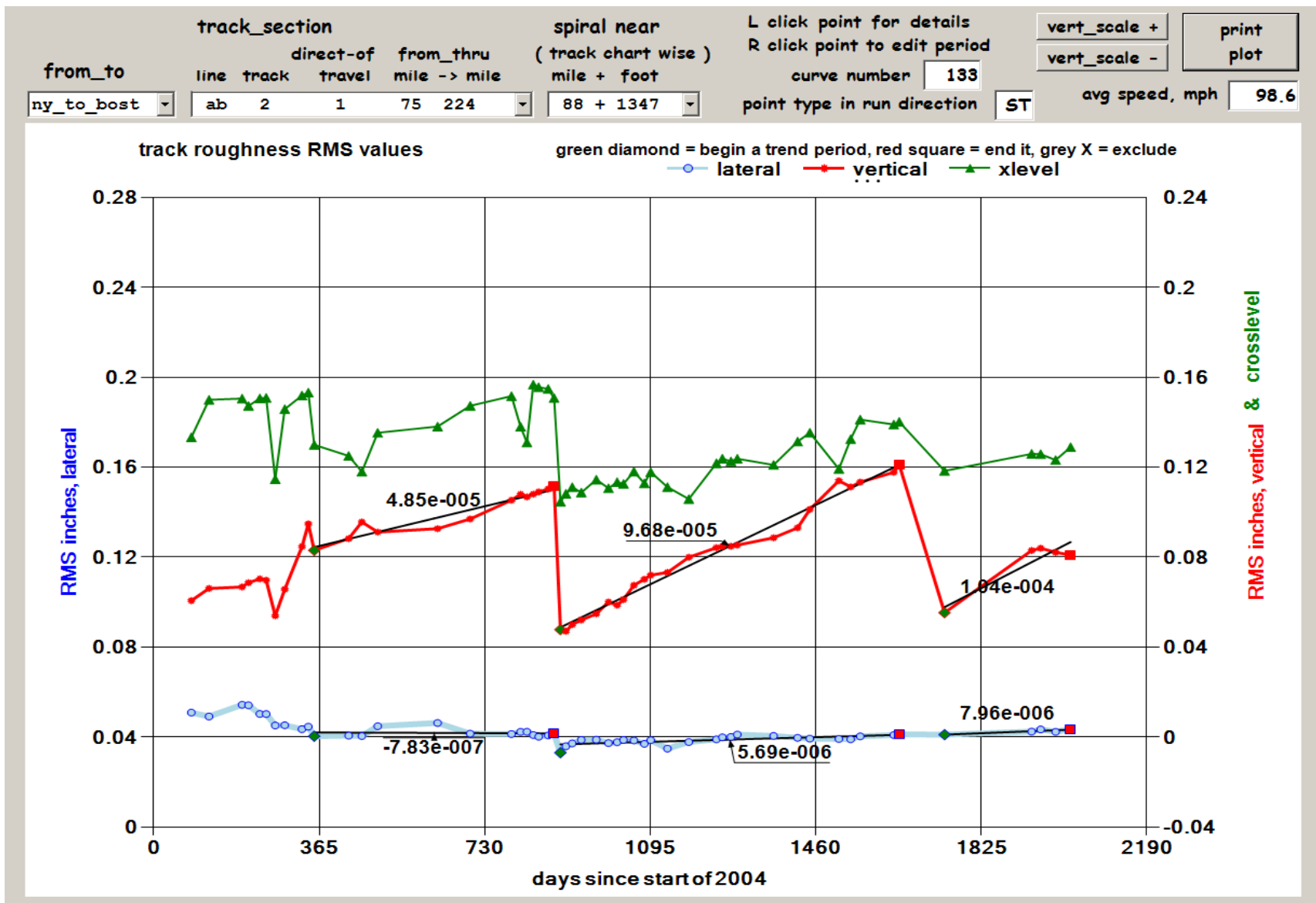


FIGURE 5: Spiral in which line is stable and surface degrades somewhat quickly.

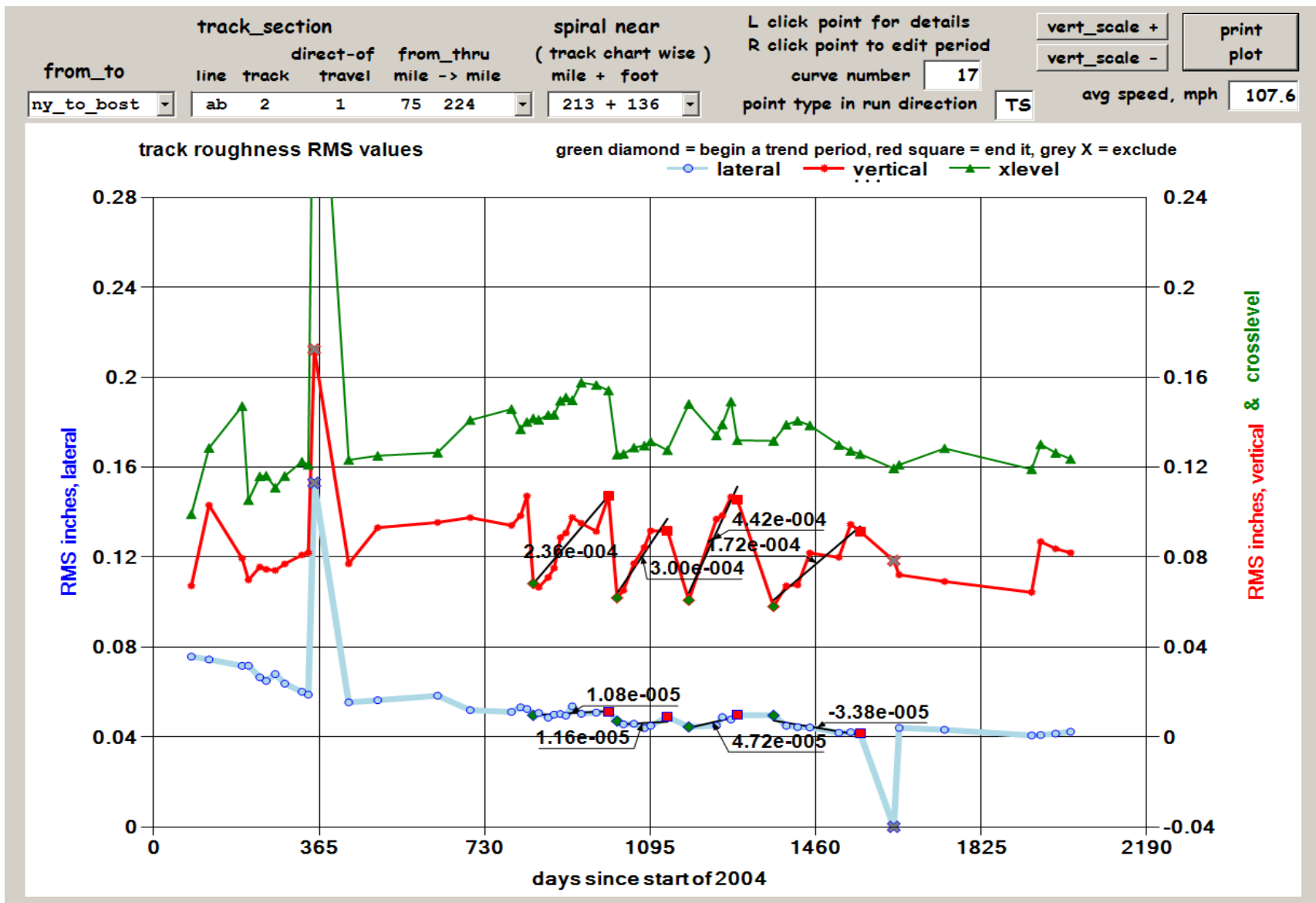


FIGURE 6: Spiral in which line is stable and surface degrades very rapidly. Two data points were manually marked with an “x” so that they would be excluded from a trend line calculation if they fell within one.

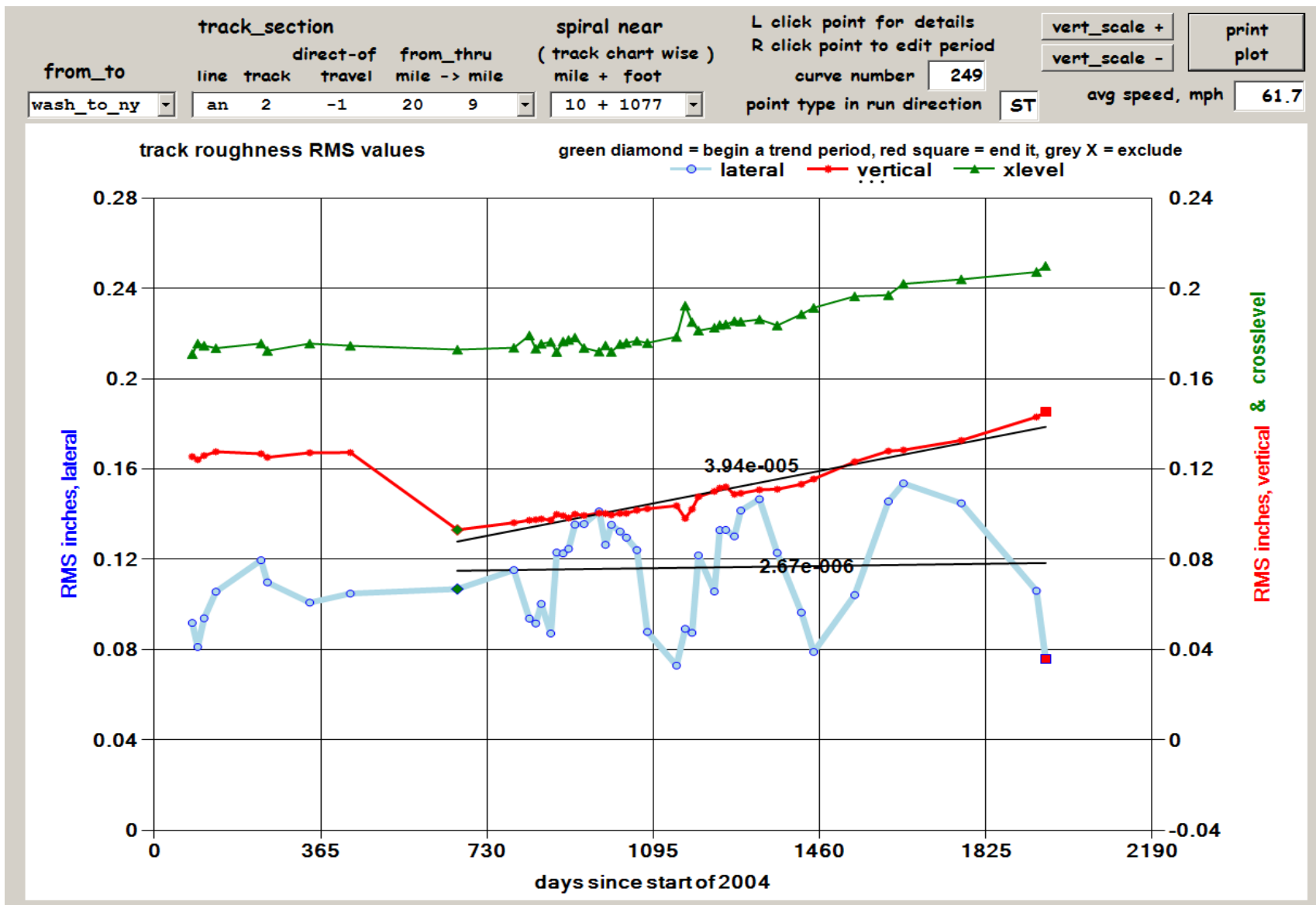


FIGURE 7: Spiral in which line roughness increases in summer and decreases in winter. Most instances are much less pronounced than this one. This behavior might be due to a combination of moderate neutral temperature and variation of lateral track strength with distance.

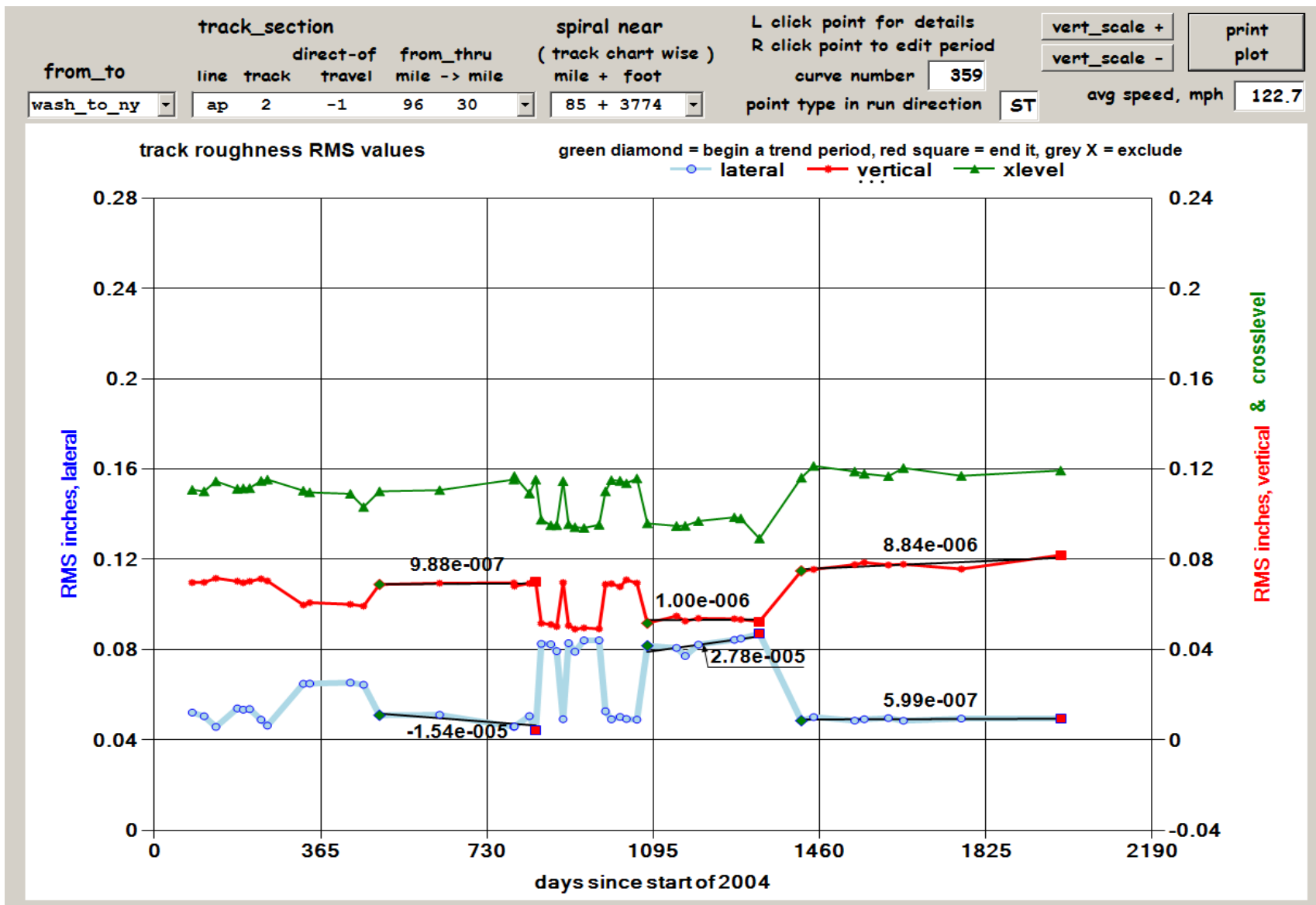


FIGURE 8: Spiral in which tamping appears to cause roughness to oscillate. In this example the oscillations are out of phase but in some examples they are in phase. A possible cause of such behavior is discussed in the text.

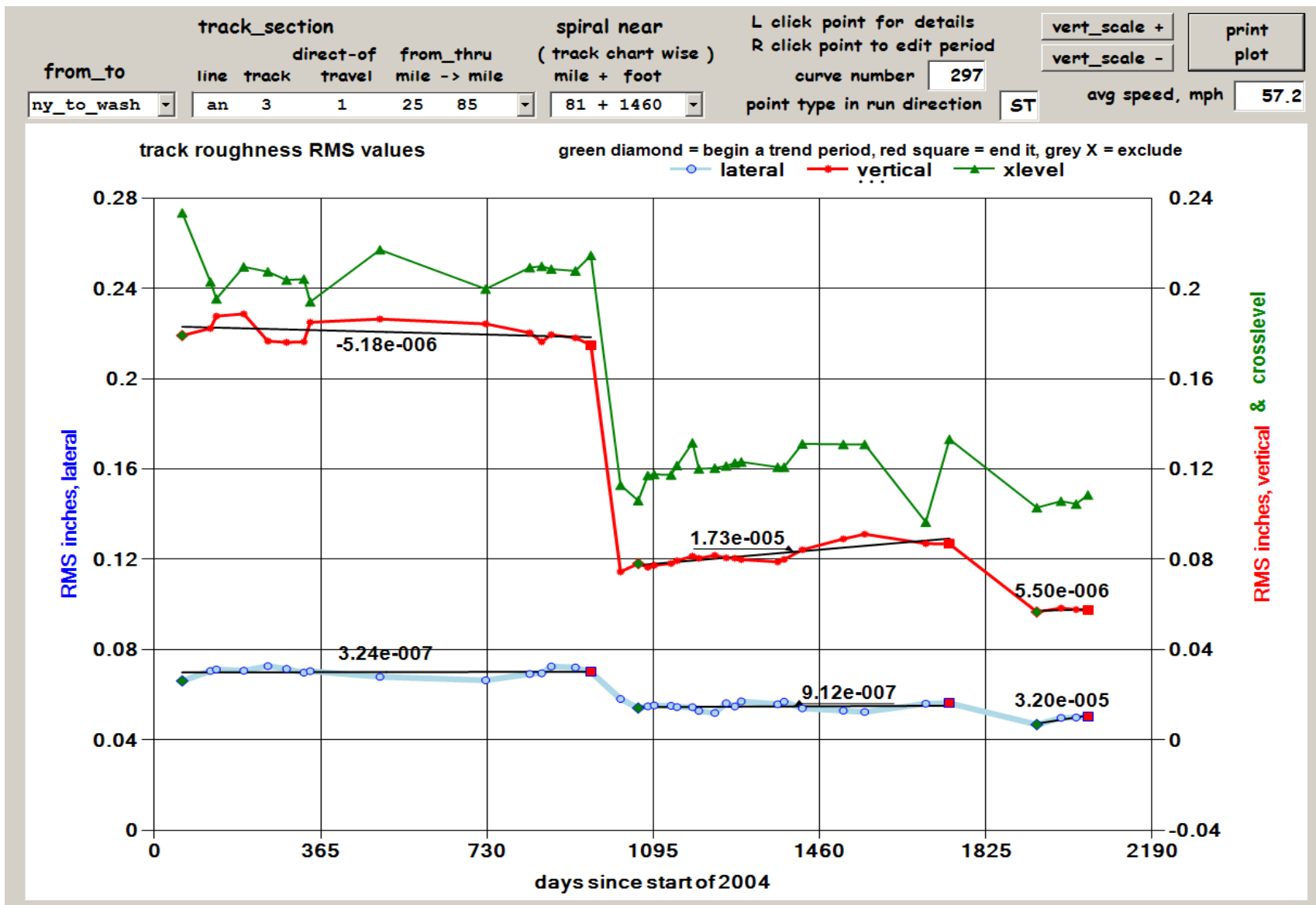


FIGURE 9: Spiral whose roughness has been reduced substantially over the course of four years. (The Boundary between Lines AN And AP Is Within Mile 77, But for Processing it is More Convenient to Put the Boundary Where the Mile Post Sequence goes from 87 to 1.)

6. PLOTS OF TRACK ROUGHNESS VERSUS TIME FOR TESTS OF IMPROVED SPIRAL GEOMETRY

Figure 10 shows the behavior of one of the spirals of Boston line track 1 curve 128 that was aligned with improved spiral geometry for Amtrak's first FRA sponsored test thereof early on November 16, 2005 as documented in reference (3). Subsequent to application of the improved geometry the line roughness has been low and steady and the surface roughness has been rising at a low rate typical for that location.

Figure 11 shows corresponding behavior of one of the spirals of Philadelphia line track 2 curve 340 that was aligned with improved spiral geometry for Amtrak's second test thereof early on October 23, 2007. This curve was given a preparatory reference tamping using a Plasser Dynacat™ 16 tool tamper in June of that year.

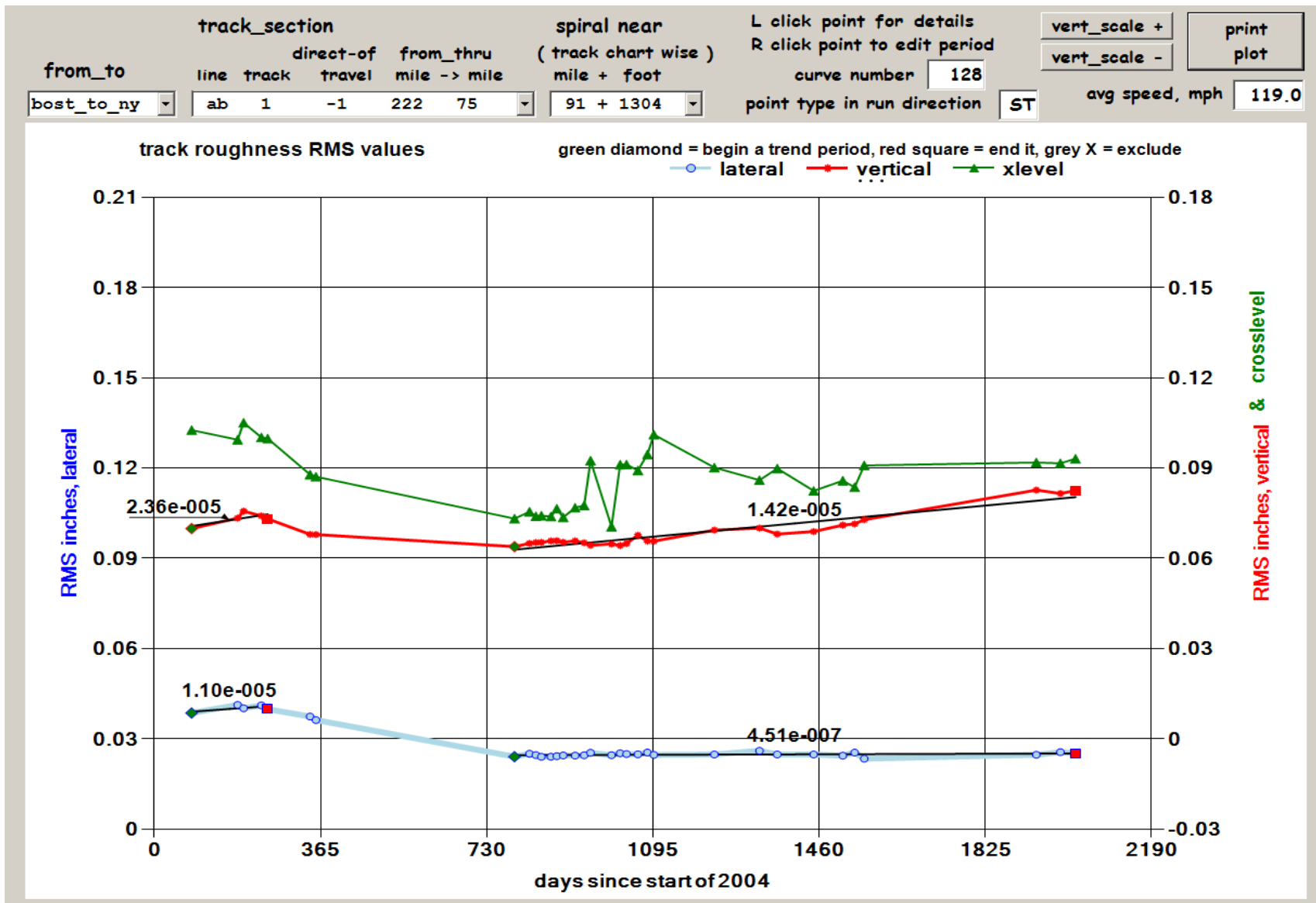


FIGURE 10: One of 2 spirals in 1st improved spiral geometry test begun toward end of 2005. Line is excellent; surface roughness rise is typical. The vertical scale is expanded compared to neighboring figures.

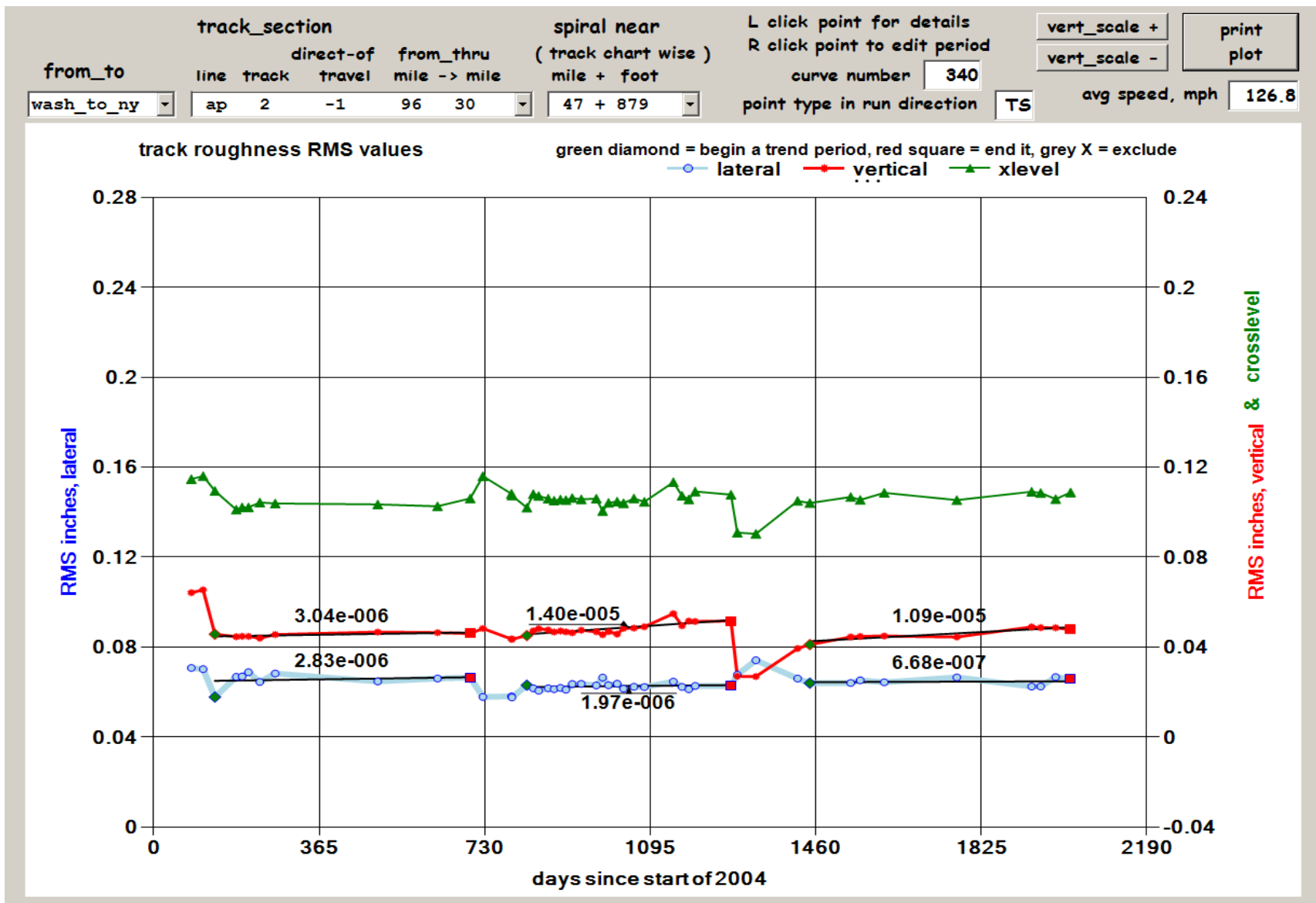


FIGURE 11: One of 2 spirals in Amtrak's 2nd improved spiral geometry test begun toward end of 2007 after reference tamping in mid 2007. An interesting aspect of this test is discussed in the text.

As can be seen in Figure 11, the reference tamping in June of 2007 achieved a substantial smoothing of the surface and crosslevel but caused some roughening of the line. Tamping in October to apply the improved geometry reduced line roughness to the level that was present before the reference tamping. However, it also caused a pronounced and very interesting roughening of the surface and crosslevel due to a circumstance that is explained below. As in the previous test, with the improved spiral geometry the line stability is good and the surface stability is typical for the location.

The lift instructions for the October tamping were generated using Plasser America's AGGS software in the usual manner and were then combined with throw and model crosslevel values calculated by the present author's K_line program. With help from Gunther Oberlechner of Plasser America it was found that the lift instructions contained an anomaly caused by an AGGS configuration option to Remove Small measured Deviations being switched on and by the Small Deviation Threshold being set at 1.0 mm. Both were default settings at the time. The dramatic and undesirable way that removing small deviations affected the lift values calculated by AGGS from the measurements made preparatory to the October tamping for the second test is shown in Figure 12. Prior to discovery of the cause of the lift problem the author added calculation of lifts to his K_line program. Figure 12 includes the lifts calculated for this case by K_line for comparison. The similarity between those lifts and the ones calculated by AGGS with small deviations not removed confirms the undesirability of removing small deviations in this particular case. It is conceivable that small deviation removal could be a cause of the oscillation exhibited in Figure 8. To find out, it would be necessary to retrieve the AGGS files used on the track of that figure and to rerun the solutions with and without small deviations removed.

Put fig 12 here

7. CONCLUSIONS

This study was undertaken to view the results of Amtrak's two tests of improved spiral geometry in a wider context and to see if improved spiral geometry could be expected to reduce track maintenance costs. Reference (5) shows that with traditional linear spirals high speed vehicles apply significant repetitive lateral force impulses to the track at each end of a spiral, and it shows that those force impulses are very much reduced when improved spiral geometry is applied. If the need for maintenance to restore track geometry were due primarily to degradation of horizontal alignment, then improved spiral geometry could be expected to reduce maintenance costs. However, this study has found that in almost all spirals in the Northeast Corridor high speed main tracks the need for maintenance to restore track geometry is due to degradation of surface before it is due to degradation of line. Thus, while one can expect improved spiral geometry to improve passenger comfort in track that has very good geometric quality, with Amtrak's existing track structures and maintenance practices one cannot expect improved spiral geometry to reduce the cost of track maintenance.

Along the way, the study has illustrated the usefulness of plots of roughness versus time for perception of track geometric behavior and has described a number of typical behaviors. It has also illustrated a problem that can sometimes be caused by a setting of one of the configuration parameters of the Plasser AGGS program.

ACKNOWLEDGMENTS

The author thanks Amtrak for access to track geometry data and for permission to publish this study thereof. The author thanks Gunther Oberlechner of Plasser America Corp. for very helpful assistance.

REFERENCES

As originally posted on an AREMA web page in 2010 this paper included two internet references numbered (1) and (4) that are no longer available. Absence of those references does not hinder understanding of the paper.

(2) Rome, H. James and Carr, G., "Track Degradation Monitoring Using Signal Matching Techniques", 6th International Heavy Haul Railway Conference, Cape Town, South Africa, April, 1997, International Heavy Haul Assoc., Virginia Beach, VA, USA.

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(5) Klauder, Louis T. Jr., Chrismer, Steven M., and Elkins, John, "Improved Spiral Geometry for High-Speed Rail and Predicted Vehicle Response", [Transportation Research Record](#), Volume 1785, Transportation Research Board, Washington, DC, USA, 2002, available at <https://www.academia.edu/5511010>

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